THE BRUSH DYNAMO-ELECTRIC MACHINE.
SIZE NO. 7, FURNISHING 16 TO 20 LIGHTS IN ONE CIRCUIT.
Length of Base, 68 inches; Diameter of Armature, 20 inches.

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The Brush Electric Light.

THE

BRUSH SYSTEM OF ELECTRIC LIGHTING,

By Charles F. Brush, M. E.

PECULIAR FEATURES OF THE DYNAMO-ELECTRIC MACHINE.

The most prominent peculiarities of the Brush dynamo-electric machine are embodied in the armature, the arrangement of field magnets, and the commutator.

The armature consists of a flat ring of soft cast-iron, revolving in its own plane. This ring is composed of two or more parts, each provided with a series of grooves, and insulated from each other, all in such a manner as effectually to prevent the induction of currents in the iron itself when it is revolved in a magnetic field. On this ring are wound eight bobbins of armature conductor, whose planes radiate from the axis of rotation.

The field magnets of the machine face both sides of the armature, in the plane of its rotation; thus both sides of the flat bobbins of armature conductor are exposed to the direct inductive influence of the magnets. This arrangement of armature and magnets differs radically from that adopted in the Gramme machine, the only other dynamo-electric machine of note in which an annular armature is employed.

Field magnets of opposite polarity are applied to diametrically opposite points of the annular armature, which then consists practically of two semi-circular magnets, having their like

poles joined. Each of these semi-circular armature magnets, if
straightened out, would be much longer than its own diameter,
and would have its bobbins wound at right angles to its axis,
and covering the greater part of its length. Now it will be
evident, that with a given length and weight of armature
conductor, a very much greater number of convolutions may
be formed on such an armature, than would be possible on
other armatures whose length from pole to pole, is short com-
pared with their diameter. But inasmuch as the field magnets
are applied to both sides and very nearly the whole length of
the long armature, the magnetic field in which the bobbins of
conductor move, is quite as intense as that obtainable when
any other form of armature is employed, and perhaps more so ;
hence the electro-motive force of current obtainable with an
armature conductor of given resistance is, *ceteris paribus*, very
much greater with this form of armature than with any other.
For a practical demonstration of this let us consider the Brush
machine known as size number 7. In this machine the resist-
ance of the armature conductor, measured through the brushes
on the commutator (the resistance is the same in all positions
of the commutator), is about four ohms ; in some machines a
trifle more, in others a trifle less, according to the purity of
the copper wire employed. When the armature is rotated at
its normal speed of seven hundred and fifty revolutions
per minute, in its normal magnetic field, the electro-motive
force developed in its conductor is sufficient to maintain its
normal volume of current through an external resistance, in-
cluding the field magnets of the machine, of fully eighty ohms ;
or through a resistance twenty times as great as its own. No
other form of dynamo-electric machine has yet shown a result
comparable with this.

This current operates from sixteen to eighteen powerful
electric lights arranged in a *single circuit*, giving to each an
arc of about two millimeters length. The resistance of these
arcs averages about four and a half ohms each, as shown by

many careful measurements of different lamps, both singly and in groups. (The measurements included the magnet helix of each lamp, the resistance of which is, however, quite small and will be given further on.)

The bobbins of wire on the armature of the Brush machine are not connected together in a single circuit, but each pair of diametrically opposite bobbins only, are connected together. The two free ends of the conductor thus formed of each pair of bobbins, are carried to the commutator and attached to diametrically opposite segments thereon, which segments are not connected with any other bobbins. Thus each pair of bobbins is entirely independent of any other pair.

In this arrangement, which secures important advantages, the Brush machine again differs radically from the Gramme, and all similar continuous-current machines.

The commutator consists of four separate rings of metal, each ring consisting of two nearly semi-circular segments, whose ends, on one side, are separated by a considerable space. This space is occupied by a piece of metal attached to an adjoining ring, and known as an " insulator." It is insulated by an air space from each of the segments between whose ends it is located, the other ends of the segments being simply separated by a single air space. The office of the " insulator" is to separate either of the brushes which collect the currents from the commutator, from both segments during a certain interval, and twice in each revolution of the commutator. During these separations, the two bobbins of wire on the armature which are connected with the pair of segments, are not only out of the general circuit, but are open circuited themselves, so that no current can circulate in them.

Each pair of bobbins on the armature is thus provided with a commutator ring, and the segments of this ring occupy the same angular position with regard to other segments, that its bobbins occupy with regard to bobbins attached to the said other segments.

It will now be seen that only one pair of armature bobbins is out of the general circuit at one time : and this is made to occur when the said bobbins are at and near the neutral points of the armature, and are not in a condition to contribute to the general current. Now, if it were not for the " insulators" above described, the idle bobbins would afford an easy passage for the current from the active bobbins, and thus destroy the efficiency of the apparatus.

The Gramme form of commutator, which is employed for the production of continuous currents in all machines other than the Brush, involves serious disadvantages, from which the Brush form of commutator is free. The principal difficulty arising from the use of the former is this :—The bobbins of wire, when at and near the neutral points of the armature, contribute little or no useful effect : but the current from the other bobbins must pass through them in order to reach the brushes, thus experiencing a considerable and entirely useless resistance, and, owing to the opposite directions of the currents through the active bobbins on opposite sides of the neutral points, these currents, by passing through the idle bobbins, tend strongly to produce " consequent" points in the armature where the neutral points should be; thus interfering seriously with the proper distribution of the armature's magnetism.

It may be argued that the evil above indicated is eliminated by allowing each of the brushes to embrace several sections of the commutator, corresponding to bobbins on both sides of each neutral point ; this is no doubt true to some extent, but another, and perhaps worse evil is thus introduced ; the bobbins corresponding to the commutator sections embraced by each brush, are short circuited in themselves, through the brush, and, owing to their comparatively small resistance, powerful currents are developed in them. These currents absorb much motive power in their production, and rapidly heat the bobbins.

Again, during each revolution of the Gramme commutator, each brush must break and make again, as many contacts as there are sections of the former, and each act involves the whole current; while with the Brush commutator, only two contacts and breaks occur with each brush in each revolution, and these successively in the different rings, so that but one-fourth of the whole current is involved at one time.

Further, the use of oil for lubrication, appears to be impracticable with the Gramme form of commutator, while it may always be employed on the Brush commutator with great advantage. Thus the durability of this commutator is made immensely greater than that of the other.

When necessary, the wearing segments of the commutator may be replaced by duplicate pieces in a very few minutes by any mechanic.

PECULIAR FEATURES OF THE LAMPS.

These are :—very great simplicity of construction ; ensuring ease of management, safety against internal derangement, and securing great regularity of working :—the double magnet circuit conveying currents of opposite direction, by means of which any number of lamps may be operated in a single circuit without any irregularity of action :—the short-circuiting safety attachment, by which any lamp offering an abnormally great resistance, owing to the final consumption of its carbons, or other cause, will, without any change of strength in the main current, automatically short-circuit the said lamp, and thus preserve the integrity of the general circuit :—the multiple sets of carbons, burning successively, without the intervention of any switching or other special mechanism, and yet securing the maintainance of the light for any desirable length of time without requiring attention : lastly, the absence of any adjustment to be made by the attendant, other than placing the carbons.

These lamps contain no clock-work or similar mechanism of any kind. The movement of the upper carbon, actuated by gravity, is controlled by a simple annular clamp which surrounds the rod carrying the carbon. When the lamp is in operation, one side of this clamp is lifted by magnetic action; this causes it to grasp and raise the rod, and thus separate the carbons. As the carbons burn away, the magnetic action diminishes, and the clamp and rod move gradually downward, maintaining only a proper separation of the carbons; but when the tilted annular clamp finally touches the supporting floor from which it started, any further downward movement will at once release the rod and allow it to slide through the clamp, until the latter is again brought into action by the increased magnetism due to the shortened arc between the carbons. In continued operation, the normal position of the clamp is in contact with its lower support, the office of the controlling magnet being to regulate the sliding of the rod through it. If, however, the rod accidentally slides too far, it will instantly and automatically be raised again, as at first, and the carbon points thus maintained in proper relation to each other.

Each magnet helix is first wound with a few layers of coarse wire, through which the main portion of the current operating the lamp passes. Over this coarse wire is wound a very much greater length of fine wire, having its ends connected with the terminals of the lamp, but in such a manner that the electric current shall pass through it in a direction opposite to that in the coarse-wire helix. Thus the fine wire forms a secondary circuit of high resistance through the lamp, which circuit is independent of the arc between the carbons, and is always closed. It follows from the difference in direction of the current in the two helices, that the fine-wire helix will constantly tend to neutralize the magnetism produced by the coarse-wire or principal helix. The number of convolutions of the fine-wire helix and its resistance, are so

proportioned to the number of convolutions in the principal helix, and its resistance together with that of the normal voltaic arc, that the magnetizing power of the latter shall be much greater than that of the former. Notwithstanding the small amount of current which passes through the fine-wire helix, (about one per cent. of the whole current) its magnetic power is very considerable, owing to its great number of convolutions.

Now when a number of regulators provided with these double helices are operated in a single circuit, great uniformity of action will be maintained owing to the peculiar function of the secondary helix. Thus, when any lamp gains more than its normal arc, the resistance of its main circuit is thereby increased ; more current is consequently shunted through its secondary helix, and the resultant magnetism is diminished, allowing the carbons to approach. On the other hand, if an arc becomes too short, its resistance is reduced, and less current is shunted through the corresponding secondary helix ; consequently the working magnetism in that lamp is increased, and its carbons are drawn further apart. Thus it will be seen that, although the general strength of the current operating a large number of these lamps does not vary, each lamp performs its regulating functions through the agency of varying magnetism, precisely as though it were the only lamp being operated.

In practice, the resistance of the fine-wire helix or helices in each lamp is rather more than four hundred and fifty ohms ; while the resistance of the coarse wire, various connections, carbons, and voltaic arc, in each lamp used with the sixteen-light machine, is about four and a half ohms. Hence not more than one per cent. of the whole current is diverted from the arc. The resistance of the coarse-wire helix, carbons, (copper-coated) connections, etc., in each lamp is very small. To determine this resistance, sixteen lamps were connected in series in the usual manner, about two hundred feet of number ten cop-

per circuit wire being used. Full length carbons were then placed
in the lamps, and the upper and lower carbon of each lamp
were connected by means of a strip of sheet copper wired to
each carbon. The resistance of the whole set was then meas-
ured, and found to be 2.10 ohms, showing a resistance for each
lamp with its carbons, of .131 ohm. This is 2.91 per cent. of
the whole resistance of the lamp when in operation. To this
loss must be added the one per cent. due to that amount of
current diverted from the arc by the fine-wire regulating helix,
making a total loss of 3.91 per cent. The remaining 96.09 per
cent. of the whole energy absorbed in each lamp, appears in
the arc between its carbons.

The shunting or short-circuiting device in each lamp, con-
sists of a small magnet core surrounded by a coarse and a fine
wire helix similar to those of the working magnet. No cur-
rent passes through the coarse wire until the magnet which it
surrounds has raised its armature. The latter, together with
the coarse wire, then form a part of the short circuit established
through the lamp. The fine-wire helix of the shunt is put in
the circuit of the fine-wire regulating helices before described.
During the normal operation of the lamp, this fine-wire helix
exercises a magnetizing influence on its enclosed core, which
thus attracts its armature with a certain degree of force, but
not enough to lift it. But when, through the exhaustion of
the carbons in the lamp, or from their failing properly to feed
together, the arc between them becomes considerably length-
ened, thus developing an abnormally great resistance in the
lamp, a greatly increased current will be shunted through the
fine-wire helix, the iron core of the latter will raise its arma-
ture, and thus establish a circuit of low resistance through the
lamp, independent of its carbons.

Evidently, when the short circuit is closed as above, very
little current circulates in the fine-wire helix, and the magnet
would drop its armature and thus open the circuit, were the

armature not retained by some means other than the magnetism due to this helix ; but it will be remembered that the coarse-wire helix surrounding the same iron core is now brought into action, and by this means the armature is retained.

.This simple cut-out mechanism effectually guards against all the dangers of general extinction, which are always present when many lamps are burned in a single circuit. It will be noticed that it operates without any change in the strength of the general current operating a system of many lamps ; and herein lies its great merit. No effect is produced in any lamp other than the faulty one, except a slight increase of brilliancy after the " cut-out" of the latter has acted. The extinction of a lamp necessarily calls attention to it at once, and the renewal of its carbons may be effected in a few seconds. As soon as the renewed carbons come into contact, a considerable portion of the current through the lamp is diverted from the magnet of the cut-out device, by the passage afforded through the carbons ; thus the retaining magnet is so weakened that it drops its armature and restores the whole current to the carbons, and the light is re-established.

The carbons employed in these lamps are covered with a thin coating of copper, and are twelve inches long. They burn without renewal, about eight hours, during which time about nine and a half inches of the positive, and four inches of the negative are consumed.

When it becomes desirable to operate the lamps more than eight hours continuously, " double-rod" lamps are used. In each of these lamps two movable rods, and two sets of carbons are employed. The rods are placed three inches apart, and each is moved and controlled in the manner already described. But both rods are actuated by a single magnet, the same as that employed in the single-rod lamp. The simple lifting mechanism connected with the magnet, is so arranged that one of the rods is lifted slightly in advance of the other. Now,

when the electric current first passes through such a lamp, the
two sets of carbons, having their members in contact, will
divide the current between them; but as soon as the
members of one set are separated by the action of the magnet,
the whole current is thrown through the other set without
showing any spark between the members of the set first sepa-
rated. When the continued action of the magnet separates the
remaining pair of carbons, the voltaic arc appears, and the
light is established. It must now be evident that the clamp
which was the last to raise its rod, will be the first to re-
lease it when a forward movement of the carbons becomes
necessary. Hence, the set of carbons which first commenced
to burn, will continue to do so until consumed; the other set
remaining separated as at first. But when the burning carbons
are exhausted, and can no longer move forward, any further
effort of the magnet to feed them, will at once bring the re-
serve set of carbons into contact; the whole current will then
pass through this set, leaving the other carbons without cur-
rent, and permanently separated. The reserve set of carbons
will now be separated by the magnet, and burn continuously.
In practice, the transfer of the voltaic arc from one set of car-
bons to the other, is accomplished instantaneously and is scarcely
noticeable.

It will be seen that this simple arrangement cannot possibly
fail in its function, there being no switch to get out of order,
or contact surfaces to become burned: further, that it is per-
fectly automatic, and operates at the instant a change becomes
necessary, and not sooner.

By means of these double-rod lamps, a system of lights may
be maintained in continuous operation sixteen hours without
requiring any attention. This is sufficient for the longest winter
night. But by introducing three rods, and three sets of car-
bons in each lamp, the lights may be maintained quite as easily
and certainly for twenty-four hours. In this case the clamps

lift their rods successively, and feed them in the reverse order, as before.

A notable feature of the Brush lamps is the absence of any adjustment requiring the attention of the user; he has but to insert the carbons, and the lamps are always ready for action.

RESULTS ATTAINED.

On August 22d, 23d and 25th, 1879, a system of very careful measurements, both electrical and dynamic, were made by thoroughly competent persons for the purpose of accurately determining the efficiency of the Brush machine and lamps. These measurements were made at the works of the Telegraph Supply Co., Cleveland. The machine used was of the size known as No. 7; its individual mark, distinguishing it from other machines of the same class, being "Y." This machine differed in no respect from others of the same size, and there is no reason to suppose that its performance was above or below the average. Sixteen lamps of the usual pattern were employed, with about two hundred feet of copper line wire No. 10.

The machine was driven by a "Buckeye" engine with automatic cut off, running at a speed of 157 revolutions per minute. This gave to the machine an average speed, during all of the experiments, of 770 revolutions per minute. The normal speed of these machines is 750 revolutions per minute, at which speed they operate sixteen lamps normally, giving to each an arc of about two millimeters length. At the speed at which these measurements were made, the sixteen arcs were perceptibly lengthened, and, of course, more than the normal amount of driving power was required. But as this produces a nearly corresponding increase of current, no attempt was made to bring the speed nearer to the normal point, because of the difficulty of changing the speed of the engine.

The machine being entirely new, the bearings heated considerably. Some driving power must have been wasted on this account.

The first electrical measurements made, were for the purpose of determining the difference of potential existing at the terminals of each lamp. This was done by a method devised by the writer. A battery of 48 small Daniell's cells was constructed on the " gravity " plan, carefully insulated, and freshly charged with sulphates of copper and zinc to insure normal action. The sixteen lamps having been adjusted to furnish arcs as nearly equal as possible, the positive terminal of one lamp was connected with the positive terminal of the battery; while the negative terminal of the same lamp was connected with the negative end of the battery, a very sensitive galvanometer being interposed. Now, it is evident that if the difference of potential between the ends of the battery is greater than that between the terminals of the lamp, current will circulate in its normal direction through the battery, and will be indicated by the galvanometer; but if this potential is less than that of the lamp, current will also flow through the battery, but in a reverse direction, and will also be indicated by the galvanometer; while if the potential is the same in both, no current will pass in either direction through the battery, and the galvanometer will show no deflection.

As was expected, the potential of the battery proved to be higher than that of the lamp. By means of a simple arrangement, any number of the battery cells could be included in the circuit at pleasure. Such a number was chosen that the galvanometer indicated no current, or currents fluctuating from zero, equally in both directions. The appearance of the arc in the lamp was then carefully noted, and the speed of the machine counted. From time to time the condition of the arc would change slightly, or the speed of the machine would vary a little, and then more or less battery would be necessary to effect the balance. When such changes occurred, another set of observations was made as before, and so on, until results corresponding to the average working of the lamp were secured. The

large number of observations made, sufficiently eliminated the error due to the fact that no fraction of a single cell of the battery could be used in the experiments. This method of measuring the difference of potential between the terminals of the lamp, proved to be extremely satisfactory and certain in its operation; the addition or subtraction of a single cell of battery being sufficient to deflect the galvanometer needle strongly to the right or left.

A series of observations was thus made on each of eleven of the sixteen lamps, selected at random, and as the results obtained from the various lamps agreed very closely, it was deemed unnecessary to carry the process further.

The difference of potential between the terminals of the *average* lamp was thus found to be equal to that of 42.46 cells of the battery, at an average speed in the machine of 770 revolutions per minute.

The next point to be determined was the resistance of the average lamp. For this purpose a resistance consisting of coils of coarse copper wire was substituted for one of the lamps, and made of such amount that 42 cells of the battery exactly balanced the difference of potential between the two ends of the resistance, while the speed of the machine was 770. This resistance wire weighed nearly seven hundred pounds, and was but slightly warmed during the experiment. Its resistance was then *immediately* measured, with much care, before any appreciable cooling could take place, and was found to be 4.51 ohms. From this resistance, balancing 42 cells of the battery, the resistance of the average lamp, corresponding to 42.46 cells of battery, is easily deduced, and is found to be 4.56 ohms. This, multiplied by sixteen, the number of lamps in circuit, gives the total resistance of the lamp circuit,—72.96 ohms. The resistance of the conducting wires between the machine and lamps was not measured, being so small as to be unimportant. The average total internal resistance of the

machine, measured through the brushes, with the commutators in various positions, and all of the conductors warm from active use, was found by careful measurement to be 10.55 ohms. Variations of only about .02 ohm were observed when the commutator was turned in different positions. This resistance, added to that of the lamps, gives a total normal internal and external resistance of 83.51 ohms, 87.36 per cent. of which (72.96 ohms) is external. Hence, 87.36 per cent. of the current developed by this machine, is available for external work.

We have found that the electro-motive force of the current overcoming a resistance of 4.56 ohms, (the resistance of one lamp), is equal to that of 42.46 cells of battery; hence the total electro-motive force of the current, overcoming the total resistance, is

$$\frac{42.46 \times 83.51}{4.56} = 777.59 \text{ cells.}$$

Assuming the electro-motive force of each cell of battery to be 1.079 volts, the electro-motive force is, $777.59 \times 1.079 = 839.02$ volts. By Ohm's well-known formula, the current in circulation is

$$\frac{839.02}{83.51} = 10.04 \text{ webers.}$$

We have next to determine what portion of the energy of the whole current was utilized in the sixteen voltaic arcs, for the development of heat and light. To this end, the resistance of the sixteen lamps, including all connections, magnet wires, carbons, etc., minus the resistance of the arcs, was determined in the manner already described, and found to be 2.1 ohms. This, subtracted from the total resistance of the lamps, 72.96 ohms, leaves 70.86 ohms as the resistance of the sixteen arcs. This is 84.85 per cent. of the resistance of the entire circuit; and as the work performed by the current in any part of the circuit is directly as the resistance of the said part, it would appear that 84.85 per cent. of the entire energy of the

current was expended in the arcs. But this is not the case, because 1 per cent. of the current passing through each lamp is diverted from the arc by the line-wire adjusting helices as before explained. Deducting 1 per cent. of 84.85, we have left 84., expressing the percentage of the entire energy of the current, appearing as heat and light in the arcs.

The electrical measurements above described, were made in the presence, and with the assistance of Mr. G. H. Wadsworth, Chief Operator and Electrician of the Western Union Telegraph Co.'s Cleveland Office.

The instruments used in measuring resistances, were a tangent galvanometer by Phelps, and a set of standard resistance coils rating from .01 ohm upward. The measurements were made by substitution.

During the progress of the electrical measurements above described, a system of careful measurements of the driving power absorbed by the machine was also made. This was done by Mr. Isaac V. Holmes, of Cleveland, a gentleman widely known as a mechanical engineer and expert. His measurements were made from indicator diagrams taken at the cylinder of the engine, and covered a period of about three hours.

The following table embodies the results obtained by Mr. Holmes:

Total power developed with the 16 light machine at 770 revolutions "closed,"	18.73 H. P.
Less friction load of engine "light,"	2.44 "
" " due to increase of load (18.73—2.44=16.29) at 5 per cent	.81 "
Total power absorbed by 16 light machine at 770 revolutions "closed,"	15.48 "
Total power developed with the 16 light machine at 770 revolutions "open,"	4.23 H. P.
Less friction load of engine "light,"	2.44 "
" " due to increase of load (4.23—2.44=1.79) at 5 per cent	.09 "
Total power absorbed by 16 light machine at 770 revolutions "open,"	1.70 "

Total power absorbed by 16 light machine at 770 revolutions,
  in the production of current, (15.48—1.70). . . . .   13.78 H. P.

NOTE—The terms "closed" and "open" refer to the external circuit of the machine. Thus, when the machine was "closed," it's current was working through the normal external resistance—that of the sixteen lamps. When "open," no current was generated.

These results agree very well with those obtained by other engineers with other machines of the same size and style. On February 6th, 1879, Mr. Noah R. Harlow, of the Lowell Water Power Co., measured the power absorbed by one of these sixteen light machines located in the Merrimack Print Works, Lowell, Mass. The speed of the machine averaged about 747 revolutions per minute while operating sixteen normal lights, and the total power absorbed under these circumstances was found to be 13.86 horse-power, including friction of dynamometer employed.

On March 18th, 1879, another machine was measured at the Dry Goods Depot of John Wanamaker, Philadelphia, Pa., by Wm. Lee Church, of the Buckeye Engine Co., of New York. Mr. Church employed the method of indicator diagrams, and obtained as a result 13.5 horse-power for the total power absorbed by the machine when operating sixteen lights. The speed of the machine was not given in his report, but was presumably about 750 revolutions per minute, as he was aware that this was the speed at which the machine should be run

The higher results obtained by Mr. Holmes may be attributed to the increased speed at which his machine was driven, and the abnormal friction at the journal bearings, due to their newness.

Referring to the electrical measurements already described, we find that we have a current of 10.04 webers, with a total resistance of 83.51 ohms Now the value in foot pounds of any current, is $C^2 Rt \times .737335$; wherein C is the current in webers, R the total resistance of the circuit in ohms, t the time in seconds, and .737335 the equivalent in foot pounds of one

weber per ohm per second. Hence, the value in foot pounds per minute, of the current from the sixteen light machine is: $10.04^2 \times 83.51 \times 60 \times .737335 = 372410.58$. This, divided by $33,000 = 11.285$, which is the energy of the current expressed in horse-power. Again,

$$\frac{11.285}{15.48} = .729 ;$$

hence, 72.9 per cent. of the total power applied at the pulley of the machine was converted into current. We have already found that 84 per cent. of the entire energy of the current appeared in the voltaic arcs. Multiplying 72.9 by .84 we have 61.24 as the percentage of the total driving power appearing in the arcs.

If we deduct friction and resistance of air from the gross power absorbed, and consider only the power actually absorbed in the production of current, as is usually done in determining the efficiency of dynamo-electric machines, we have,

$$\frac{11.285}{13.78} = .8189 ;$$

or 81.89 per cent. of the absorbed power converted into current. As before, 84 per cent. of this current appearing in the arcs, we have $81.89 \times .84 = 68.79$ per cent of the entire power absorbed in the production of current, present as heat and light in the sixteen arcs.

RECAPITULATION.

Resistance of dynamo-electric machine....................	10.55 ohms.
" " external circuit........................	72.96 "
Total resistance of circuit............................	83.51 "
Resistance of 16 voltaic arcs.........................	70.86 "
Percentage of current available for external work.........	87.36
Percentage of current appearing as heat and light in 16 voltaic arcs.......................................	84.00
Electro-motive force of current........................	839.02 volts.
Volume of current....................................	10.04 webers

Total driving power required............................   15.48 H. P.
Driving power absorbed in production of current..........   13.78   ''
Energy of current expressed in horse-power...............   11.285   ''
Percentage of gross power converted into current.........   72.90
Percentage of absorbed power converted into current.....   81.89
Percentage of gross power appearing in arcs.............   61.24
Percentage of absorbed power appearing in arcs..........   68.79

These results require no comment. Their excellence is apparent. They have not yet been approached by those of any other dynamo-electric apparatus operating multiple lights; or even by those operating single lights.

Mr. Louis Schwendler, in his excellent "Report on the results obtained by the *electric light experiments*," dated London, Nov. 1st, 1878, gives the percentage of absorbed power appearing in the electric lamp, in the cases of four dynamo-electric machines. The lowest result given was 30, and the highest 62 per cent.; the latter with a machine of the Siemens type. This is much the highest efficiency we have yet seen reported authentically, of any dynamo-electric machine. The result was obtained only under the most favorable circumstances, as pointed out by Mr. Schwendler, viz.: with a machine furnishing a single light, and developing a large volume of current (29.5 webers), of comparatively low electro-motive force.

The Brush machine, developing a much smaller volume of current, of a vastly greater electro-motive force, and operating sixteen lights, yet shows a much higher efficiency viz.: 68.79 per cent.

From the peculiar nature of the Brush system of lighting, arise very important advantages over other systems, not yet touched upon. We refer to the great ease with which the lights may be operated a long distance from the dynamo-electric machine, and the small loss of effect occasioned by so doing.

When a separate dynamo-electric machine is employed for each light, according to the systems which appear to be most in favor in England and France, or when the same machine

furnishes several currents, each operating a light, then each lamp must be independently connected with the machine, and the whole loss of current occasioned by the resistance of the pair of conducting wires, must fall upon each single lamp. There must also be as many complete sets of conductors as there are lamps.

In the Brush system, one pair of conductors is sufficient for all the lamps, no matter what their number may be; and the loss due to these conductors falls not on each lamp, but is equally divided between all. Hence, in order to reduce the loss in each light due to the conductors in the single light system, to the same amount as that in each light in the multiple-light system, the size of the conductors in the former case must be to that of the conductors in the latter case, directly as the number of lights operated in the multiple-light system, to unity. And, since the single-light system requires as many sets of conductors as there are lamps, while the multiple-light system requires but one set of conductors, the total weight of conductors required for a given number of lamps, (keeping the total loss of effect due to this cause the same in both systems,) is as one, for the multiple-light system, to the square of the number of lamps for the single-light system. To illustrate: suppose sixteen lights are operated at a given distance from the dynamo-electric machine or machines, and the loss of current due to resistance of conductors is limited to a certain amount; and let the weight of conductors required in the multiple-light system be represented by 1; then the weight of conductors required in the single-light system will be $16^2 = 256$. Hence, in operating a large number of lights at a long distance from the source of power by the single-light system, either an enormously expensive system of conductors must be employed, or else a great part of the whole energy of the currents will be wasted in overcoming the resistance of the smaller conductors.

This objection to the single-light system is fatal, when any

considerable separation of the machines and lamps becomes necessary.

The Brush system of lighting being free from this defect, the lights may be maintained at a great distance from the source of power with very little loss of effect, and by means of conductors of moderate size and cost. The resistance of number 10 (Stubb's gauge) copper wire of commercial purity, is about .6 ohm per thousand feet; therefore 7600 feet of such a conductor will equal in resistance, only one of the sixteen lamps already described:

$$\frac{4.56.}{.6} \times 1000 = 7600.$$

so that fifteen lamps of full power could be operated through such a conductor of this length; or the whole sixteen, with a loss of only about six per cent. in effect. Only fifty per cent. of the total effect would be sacrificed by working through such a conductor more than eleven miles in length, (60800 feet) and this loss might be reduced one half by doubling the size of the conductor, which would still be of moderate dimensions.

No reference has yet been made to the use of more than sixteen lamps in the circuit of the No. 7 machine; but 17 or 18 lamps are often employed with the machine running at its normal speed of 750 revolutions per minute, and with good effect, although the total light produced is less than with sixteen lamps. At the speed at which the above described measurements were made, viz. 770 revolutions, 19 or 20 lamps may be burned with tolerably good effect, although the maximum amount of light is obtained with 16.

As many as 33 lamps have been operated simultaneously in the circuit of a No. 7 machine running at a speed of 800 revolutions per minute, with an arc of appreciable length in each lamp; but the total light produced was less than half that obtained when 16 or 17 lamps were employed. When the number of lamps operated by the No. 7 machine, running at full

speed, is reduced below 16, the brilliancy of the remaining lights is of course increased, but not in proportion to the reduction in number. Hence the total amount of light is diminished. The *quantity* and *intensity* of the current are such as to produce the maximum light in 16 arcs.

At the time Mr. Holmes measured the power required to drive the sixteen-light machine, he also measured that required by a six-light machine of the size and style known as " No. 5."

This machine furnished six beautiful lights in single circuit, similar to those of the No. 7 machine, but with somewhat shorter arcs. (It will be remembered that the No. 7 machine was driven above its normal rate of speed.) The total power required to drive this machine was 4.5 horse power. The following are Mr. Holmes' figures :

Total power developed with the 6 light machine at 922 revo-
    lutions " closed,"..................................... 7.18 H. P.
Less friction load of engine " light,"..................... 2.44 "
    "   "   due to increase of load (7.18—2.44=4.74) at 5
    per cent... .24 "
Total power required by 6 light machine................... 4.50 "
    No measurements of the current from this machine were made.

REMARKS.

Much has been written by eminent electricians, and others, about the enormous loss of total lighting effect which follows the use of more than one centre of light in an electric circuit. Some state that the total light diminishes as the square of the number of lights increases ; others, that the loss is as the cube of the number of lights.

These extraordinary assertions are made without any reference to the energy or character of the current employed, and are never supported by any experimental data.

The experience of the writer has uniformly shown that when a small amount of electrical energy is expended at several points, very little or no light results : while if the same energy

be properly expended at one point, a large amount of light may be evolved. On the other hand, when a *large* amount of current energy is properly expended at a number of points not too great, the total light produced may nearly equal that evolved when the whole energy is concentrated at one point.

A certain amount of energy is required before any light at all is produced, and if the division falls below this point nothing in the way of light results. But after a certain point is reached, at which a good light is produced, then the increase of light appears to be almost directly as the increase of energy exhibited in the arc, the length of the latter remaining constant. Mr. Schwendler's experience here appears to coincide with our own. In his report, before mentioned, he says: "If we make the highly probable supposition that the resistance of an arc of constant length is inversely proportional to the current which passes through, then the light produced would be proportional to the current. This appears to be the case." Again he says: "Although the light must be very nearly proportional to the total energy consumed in the arc, the resistance of the arc decreasing with the increase of current, it follows that the light *cannot* be proportional to the square of the current."

It is argued by many, that an increase of energy in the arc, produces a corresponding increase of temperature of the carbons, and that, according to a well known law, the light must increase much faster than the temperature. But in fact, after a certain point is reached, the temperature of the positive or light-giving carbon does *not* increase with increase of current, but the area of surface heated to maximum, increases almost directly with the current. The "certain point" several times alluded to, is at that stage of the process when vaporization takes place over a well defined spot on the positive carbon. Obviously, when rapid evaporation has commenced, the temperature of the carbon cannot be increased at that point, and an increase in the

amount of heat evolved, can only result in an increase in the rapidity of vaporization, or vaporization over an increased area.

A careful study of the voltaic arc, and of the carbon points after being used with currents of various strength, cannot fail to convince the most skeptical, of the truth of these assertions.

Quite contradictory to the spirit of those portions of Mr. Schwendler's report—already quoted, he says in another place: "If more than one light is produced in the same circuit, by the same current, the external or available light becomes rapidly dearer with increase of the number of lights produced. For this reason already, if not for many others, the *division of light* must result in an engineering failure."

It seems scarcely possible that Mr. Schwendler could have overlooked the obvious fact, that a current representing a given amount of energy, and adapted to produce the maximum light from one center, may, by having its dimensions suitably altered, *i. e.* its electro-motive force increased, and its volume diminished, while its energy remains the same, be adapted to produce its maximum light from several small centers, instead of from one large one, (provided, of course, the energy at each center is not reduced below the "certain point" before defined.) Yet he seems to have overlooked, or entirely ignored, this fact.

The performance of the No. 7 Brush machine with its sixteen lamps, already detailed, proves unquestionably that the division of a large current energy among many lights in the same circuit, or more properly, the *multiplication* of lights on a single circuit, has resulted in a great engineering *success.*

The votaries of the single-light system would advocate in place of the single No. 7 Brush machine, the use of *sixteen* small machines, with their costly system of conductors. *Each* of these would require as much attendance, and involve as much expense for repairs, as the single large machine. At least fifty per cent. and probably one hundred per cent. more driving power would

be required to produce sixteen lights of the same size, and the first cost of the apparatus would be vastly greater. Further, if the lights were required at any considerable distance from the source of power, the single-light system must prove *entirely* im. practicable.

CLEVELAND. September, 1879.

In the preceding pages Mr. Brush has fully described his Electric Light System, but has omitted to state, what we think should be stated, viz.: that his system has been very extensively adopted in this country; practically to the exclusion of all others. Its very great advantages as an illuminating agent have attracted the attention of large users of light throughout the country, and although, at this date, (September, 1879,) scarcely a year has elapsed since orders were first accepted for the present apparatus, *seven hundred lights* have been *sold* for actual practical use. Orders are rapidly coming in, and our establishment (five floors, 50x100 feet) is driven to its utmost capacity, but cannot keep actual purchasers supplied without considerable delay. This phenomenal success has not been based upon mere enthusiasm about the beauty of electric light, but upon the solid fact that actual trial has proved the Brush Electric Light to be the very best and cheapest lighting agent, where large amounts of light are needed.

The case of the famous Riverside Worsted Mills at Providence, R. I., will serve well to illustrate what Mr. Brush's system is capable of accomplishing. Having so great an amount of orders ahead, they were compelled to run their entire establishment, without an hour's stoppage, night or day. Their gas bills, with gas at about $2.00 per M. cubic feet, ran up to nearly $17,000 per year. Learning of the success of the Brush light, they were led to purchase a large machine, yielding sixteen powerful lights in one circuit. With this they lit up their weaving shed in the most satisfactory manner, the weavers being completely captivated with the "new light." An estimate of the relative actual cost of the old and new lights indicated a great saving, and the light proving fully successful—strong, steady, clear, safe, free from radiated heat, and showing natural colors,—it was decided to adopt it throughout the establishment, and an order was given for two more of the large sixteen-light machines, which have since been in use with the most satisfactory results. Very recently quite an addition has been made to this establishment, and an order has just been received for two more sixteen-light machines for the new building, thus making *eighty* lights in all. With these eighty lamps the total actual cost of electric light, including the items of carbon consumed, power, interest on investment, wear and tear, and attendance, will not exceed $2.00 per hour. If gas was to be used as before, it would cost not less than $8.00 per hour—and not yield a satisfactory light. Comment is unnecessary.

Among other large purchasers of Brush lights may be mentioned the Grand Depot of John Wanamaker, Philadelphia, 56 lights; The Oswego Falls Woolen Mills, 54 lights; The Conant Thread Co., Pawtucket. R. I., 36 lights; The Iron Pier at Coney Island, 23 lights; and 16 to 18 lights in each of the following places: Pottstown Iron Co., Pottstown, Pa.; Park Bros., Steel Co., Pittsburgh, Pa.; Prospect Park, Niagara Falls; S. S. Assembly, Chautauqua Lake; Mechanics' Pavilion, San Francisco, Cal.; Globe Mills, Woonsocket, R. I.; Atlantic Mills, Providence, R. I.; Cheney Bros., Silk Works, So. Manchester, Conn.; Bay State Iron Co., Boston, Mass.; Norway Iron Co., Boston, Mass.; California Electric Light Co., San Francico; besides a large number in smaller establishments.

The above facts clearly indicate that, although electric light abroad has been an economic as well as an engineering failure, in this country it is a complete success, and the Brush Electric Light must henceforth be counted amongst the fully practical illuminating agents, and the only one that can fill the demand completely where large amounts of lights are used. We shall be pleased to furnish to parties interested in the subject, detailed information regarding the Brush apparatus.　　　　　　　　　　　　　　　　　　　　TELEGRAPH SUPPLY CO.,
CLEVELAND, OHIO, U. S. A.,
Sole Manufacturers.